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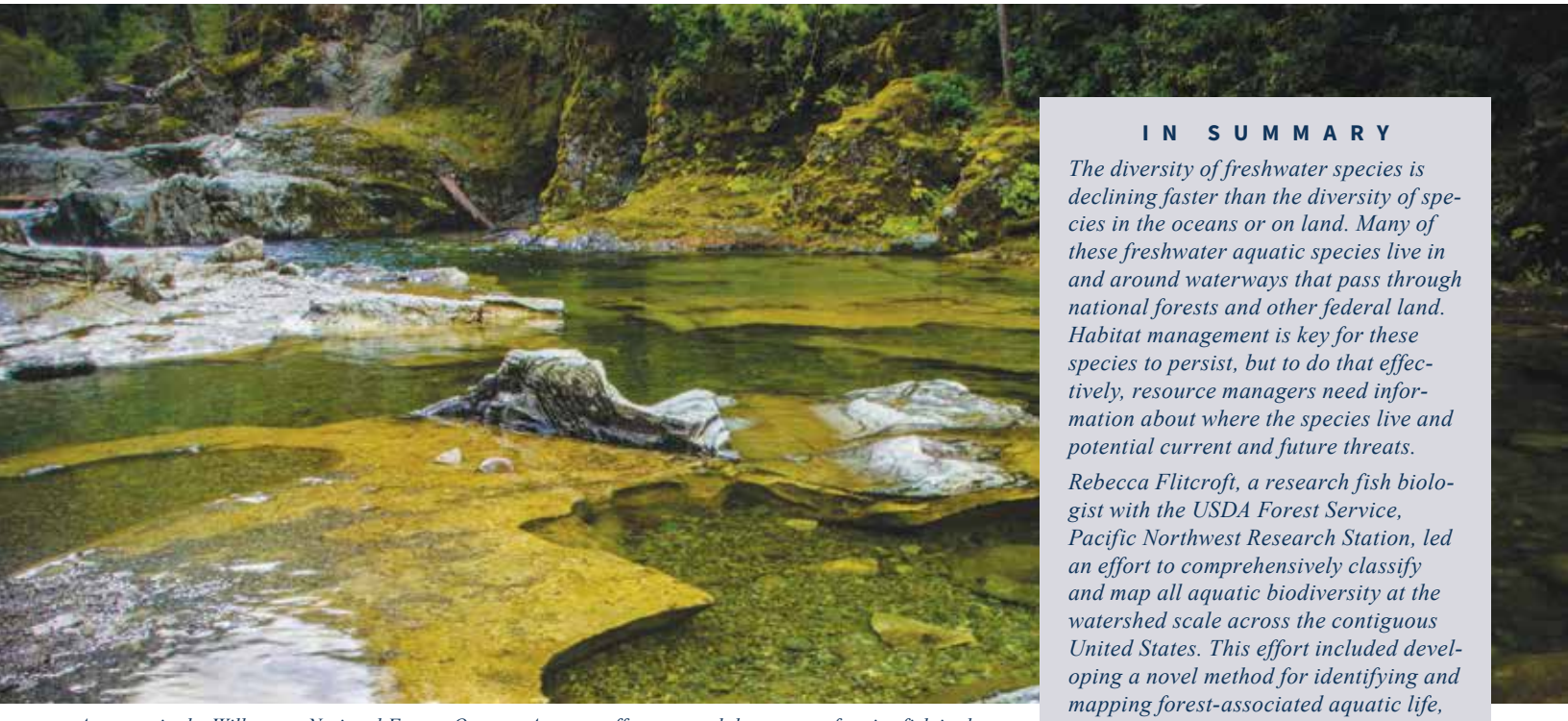
Science FINDINGS

INSIDE

"Science affects the way we think together."
Lewis Thomas

Living Water: Mapping Aquatic Biodiversity



A stream in the Willamette National Forest, Oregon. A recent effort mapped the ranges of native fish in the contiguous United States with forest cover, finding that 554 species have least 50 percent of their range in watersheds where forest covers at least 50 percent of the area.

IN SUMMARY

The diversity of freshwater species is declining faster than the diversity of species in the oceans or on land. Many of these freshwater aquatic species live in and around waterways that pass through national forests and other federal land. Habitat management is key for these species to persist, but to do that effectively, resource managers need information about where the species live and potential current and future threats.

Rebecca Flitcroft, a research fish biologist with the USDA Forest Service, Pacific Northwest Research Station, led an effort to comprehensively classify and map all aquatic biodiversity at the watershed scale across the contiguous United States. This effort included developing a novel method for identifying and mapping forest-associated aquatic life, as well as mapping stressors related to climate and human development in relation to imperiled species.

This work is visually summarized in the National Aquatic Biodiversity Assessment Dashboard, an interactive, online tool that includes maps and downloadable species lists for native fish, mussels, crayfish, amphibians, and reptiles in specific watersheds, national forests, and ecoregions. It also includes filters to identify endangered aquatic species within a particular national forest or ecoregion. This information enables forest managers to identify the forest-associated species in their management areas and gives planners a way to compare aquatic biodiversity, threats, and priority areas for protection at regional or national scales.

"We should preserve every scrap of biodiversity as priceless while we learn to use it and come to understand what it means to humanity."

—Edward O. Wilson, biologist

As a child, perhaps you were fortunate enough to have a creek or riverbank to explore. A place where you could while away a summer afternoon turning over rocks or casting a line. The rough-skinned newt with its orange belly, which you might have found while on a camping trip in the Oregon Coast Range, or the yellow perch you might have caught in an inland reservoir, are just two of the roughly 2,200 species of native freshwater fish, mussels, crayfish, reptiles, and amphibians in the waters of the lower 48 states. That may seem like a lot, but the diversity of freshwater species is declining faster than the diversity of marine or terrestrial species.

"Knowing what native species are present is a critical starting point in species or community-driven ecosystem planning and recovery," says Rebecca Flitcroft, research fish biologist with the Pacific Northwest Research Station of the USDA Forest Service.

Many aquatic species live in and around waterways that pass through national forests and other federal land. Habitat management is key for these species to persist, but to do

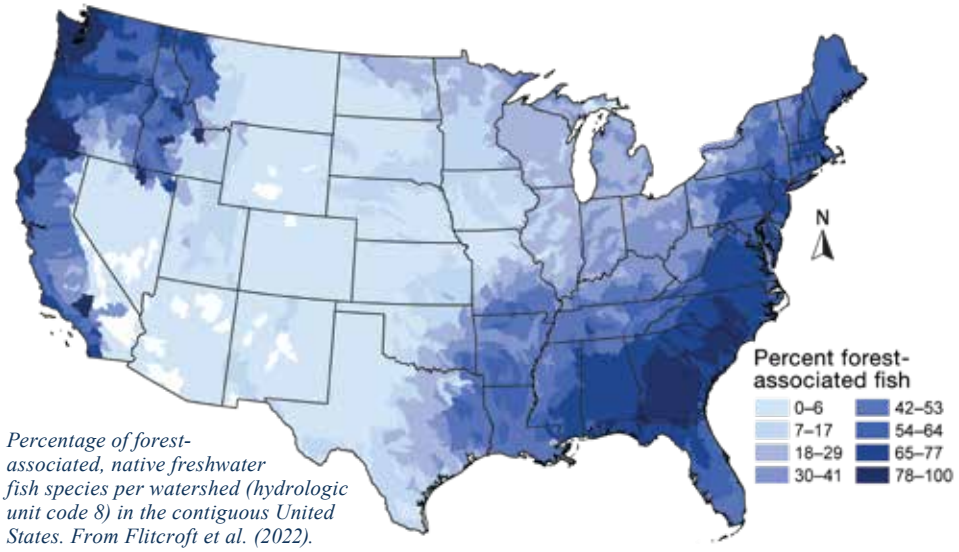
that effectively, resource managers need information about where the species live and potential current and future threats.

In our modern world, where data on everything seems to be readily available, one might think that this kind of fine-scale information would be just a few clicks away. It's not. Or at least it wasn't until recently, when Flitcroft and colleagues took on the task of compiling what is now the first comprehensive catalog of aquatic biological diversity, as well as forest-associated aquatic species and their habitats in the contiguous United States.

This work is intended to provide forest managers with a more complete set of information, knowing that they can't plan for a future with resilient aquatic ecosystems if they don't know what species live there, or how vulnerable they may be to shifting ecosystem conditions.

A National Inventory

Flitcroft and Gwendolynn Bury, a research fellow through the Oak Ridge Institute of Science and Education, initially set out to describe patterns of aquatic biota across the contiguous United States. Using datasets from the NatureServe Network and other sources, they linked patterns of aquatic biota with current land-use threats and vulnerability to future events. This comprehensive biodiversity research became an integral part of the *2020 Resource Planning Act Assessment*—a report issued every 10 years on the status, trends,



Percentage of forest-associated, native freshwater fish species per watershed (hydrologic unit code 8) in the contiguous United States. From Flitcroft et al. (2022).

and projected futures of the nation's renewable resources on all forest- and rangelands.

They also worked with partners at the Forest Service's Rocky Mountain Research Station to identify local vulnerability of aquatic-dependent species in terms of human-caused stressors (such as land development, agriculture, pipelines, and mining) as well as places where climate change is likely to compound existing vulnerabilities.

Ultimately the interdisciplinary team included taxonomic experts, geographers, climate modelers, water resource experts, biologists, and statisticians from multiple institutions to address forest management questions. They also consulted with national forest staff to

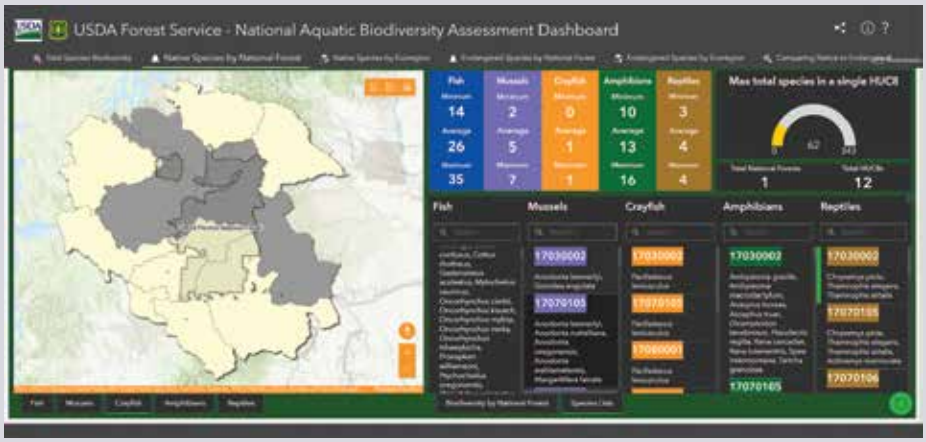
National Aquatic Biodiversity Assessment Dashboard

This interactive, online tool illustrates the diversity of aquatic species in every national forest in the lower 48 states. Users can choose to explore by watershed, national forest, or ecoregion to see the number and species of fish, mussels, crayfish, amphibians, and reptiles found in the selected area. Users can also see which of those species are protected under the U.S. Endangered Species Act and download species lists.

"I think it's important that we have an overall understanding of the diversity of species that we as an agency have to maintain," says James Capurso, the Forest Service's regional fisheries biologist for the Pacific Northwest. "This is a really great tool that helps us do that. It's user-friendly—everybody can get in there and have an appreciation for all the aquatic species across the United States."

FUN FACTS

- With 298 native aquatic species, Land Between the Lakes National Recreation Area in Kentucky and Tennessee hosts the most aquatic biodiversity on land managed by the Forest Service.
- In the Pacific Northwest, Gifford Pinchot and Mount Hood National Forests top the list with 63 and 62 native aquatic species, respectively.



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Forest Service

KEY FINDINGS

- Federal lands, which may be managed for conservation of biodiversity, are concentrated in the Western United States, whereas the aquatic-dependent biodiversity is greatest in the Eastern United States
- In particular, the Northeastern and Southeastern United States have concentrations of endangered and threatened species of fish, crayfish, and mussels.
- The conversion of land to more developed uses is the greatest overall land-use stressor for native ecosystems across the contiguous United States.
- Federal lands are less likely to be developed, but because of their location, are projected to experience more climate stress compared with other lands. This potentially limits their future ability to function as climate refugia for native aquatic biota.

identify ways in which the research could be of the greatest help in forest planning.

The work took years. The final product is perhaps the most detailed look at aquatic biodiversity in the United States and reveals vast differences among regions in terms of the variety of freshwater life. The national inventory of aquatic biodiversity was recently released as an interactive online tool—the National Aquatic Biodiversity Assessment Dashboard. The dashboard can be used to search by individual forest to map and acquire lists of species that are present in specific watersheds, national forests, or ecoregions in the lower 48 states. The information can also be sorted to reveal the endangered aquatic species at those three scales.

In related work, the Forest Service's Office of Sustainability and Climate asked Flitcroft to look specifically at the biodiversity of aquatic species that rely on forests.

"The terrestrial data was pretty comprehensive, but the aquatic part underrepresented the relationships aquatic biota had with forests," Flitcroft says. "We were interested in all the aquatic biota, but all the datasets we looked at were species specific."

The task came down to mapping each species' habitat and range, one by one, quantifying the amount of forest cover for each watershed they were found in, linking each species with the resulting forest-cover calculation, and putting all of this information into maps.

"I come across databases all the time, and I was sure somebody had already done this. But no." Flitcroft says.

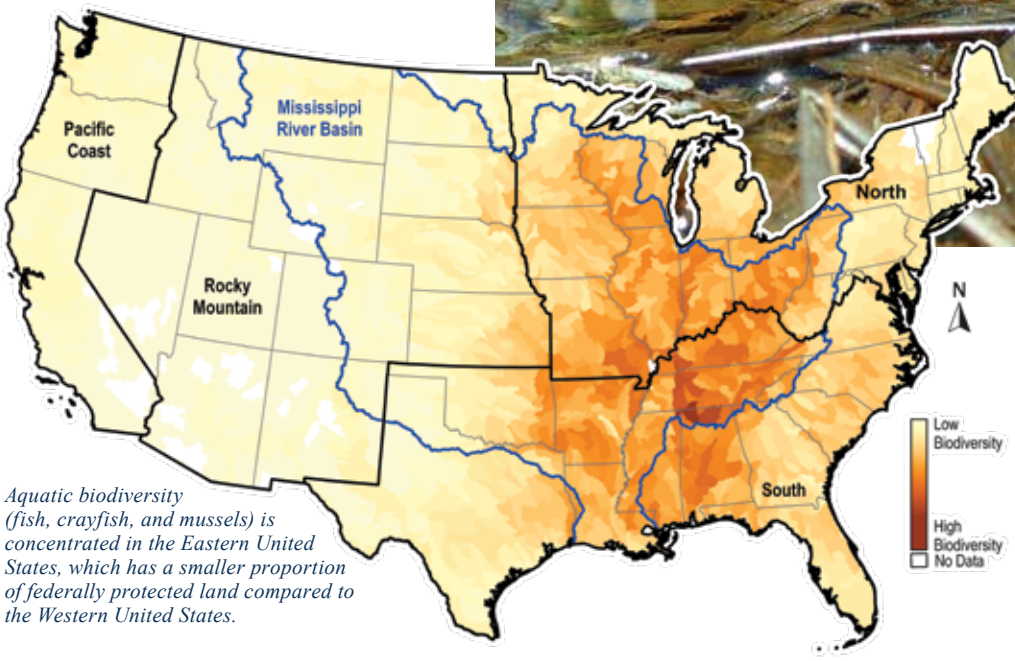
Determining the importance of forest cover to specific species was a major part of the work. If at least 75 percent of a species' range was 75 percent covered by forest, the logical conclusion is that the species is "forest dependent." The team reasoned that species with 50 percent of their range in watersheds that were 50 percent covered by forest should be classified as "forest associated." Flitcroft and Bury were able to link species ranges with forest cover and map them with such fine precision that this became a new addition to the scientific record.

The Importance of Biodiversity

Biodiversity is a measure of the variety of organisms in a specific area and is a key attribute of healthy ecosystems. The variety of life makes ecosystems—with their infinitely complex, interactive, and symbiotic elements—operate as a functional whole.

Flitcroft points out that biodiversity naturally varies in response to geologic history, tectonic activity, and the conditions of different ecoregions. Declining biodiversity is strongly linked to human actions that have changed ecosystems, leading to declines in habitat quality, quantity, and connectivity both on land and in water.

"Tracking patterns in biodiversity is key to informing management in places that may be particularly vulnerable to current and emerging threats," she says.



Aquatic biodiversity (fish, crayfish, and mussels) is concentrated in the Eastern United States, which has a smaller proportion of federally protected land compared to the Western United States.

The data indicate that the Mississippi River Basin and Southeastern United States host the highest levels of aquatic biodiversity in the lower 48 states. This is largely a function of geologic age: the eastern side of the North American continent is older than the western side. As a result, species in the U.S. East have had a longer time to differentiate.

"The Southeast pocket also didn't have glaciers during the last Ice Age, which left it unaffected, while the North and West were covered in ice," explains Brooke Penaluna, a fisheries biologist with the Pacific Northwest Research Station who contributed to the project.

*Yosemite toad (*Anaxyrus canorus*), endemic to the Sierra Nevada, California. Photo by Rachel van Horne, USDA Forest Service.*

*Western pearlshell (*Margaritifera falcata*), a freshwater mussel found in streams in the Western United States. Photo by Roger Tabor, U.S. Fish and Wildlife Service.*

Although the Eastern United States is more biologically diverse, that biodiversity faces greater threats than in the West. Flitcroft points out that fish, crayfish, and mussels in the Northeast and Southeast could be at higher risk than in other parts of the country. For one, the human population density is greater in the East, and with that comes greater densities of land development, industry, and roads. There's also less federally managed land in the East, and thus, fewer acres of federally protected habitat.

"It's where all the stressors collide," Flitcroft says. "Biodiversity is high, but the region is aligned with every stress you can imagine. It's where we're seeing the biggest collision of forest with agriculture, development, mining, and drilling."

By contrast, aquatic biodiversity is less diverse west of the Mississippi River but receives greater federal protections because of the greater amount of federally managed land. Despite these protections, federal lands, such as those managed by the Forest Service and the National Park Service, are more vulnerable to the stresses associated with climate change. A good portion of federal land in the West is at higher elevations and projected to experience high climate-related stress, or in areas with extreme temperatures (think Mojave National Preserve). That vulnerability could limit the ability of those lands to act as a refuge for native aquatic species, according to Flitcroft.

"It's kind of perplexing," Flitcroft says. "Because we have all these protections from development of federal land, people think that they are refugia for native species. But federal lands weren't originally identified for their resistance to climate change. The West is just more vulnerable."

Those vulnerabilities are most prevalent in the vast Rocky Mountain and Pacific coast regions, she says.

Conservation Planning

Flitcroft and Penaluna envision their detailed compilation of species diversity informing future management of federal lands. Federal agencies already are tasked with managing for the health of ecosystems in their regions, and this recent research will help them identify where to prioritize habitat conservation.

*Peamouth (*Mylocheilus caurinus*), a freshwater fish native to the Pacific Northwest that can tolerate saltwater. Photo by Roger Tabor, U.S. Fish and Wildlife Service.*

LAND MANAGEMENT IMPLICATIONS

- The vulnerability of native aquatic species, particularly to human development and projected climate change, highlights the importance of prioritizing habitat conservation actions across ownership boundaries in response to local and regional threats.
- The amount of federally managed lands in the Western United States presents an opportunity for biodiversity conservation at broad spatial scales commensurate with climate stress and wildfire.
- Tools such as the National Aquatic Biodiversity Assessment Dashboard can facilitate planning that supports ecosystem resilience to wildfire and other disturbances.

*Columbia torrent salamader (*Rhyacotriton kezeri*), only found in coastal Oregon and Washington. Photo by Chris Cousins, U.S. Fish and Wildlife Service.*

"It highlights the importance of prioritizing habitat conservation actions in response to local and regional threats," Flitcroft says.

Forest Service managers in the Pacific Northwest and Southeastern United States have requested datasets from the scientists so they can update their species lists for forest plan revisions and to identify emerging threats to native species.

Their work is likely to change the way forest and regional managers approach their jobs of protecting aquatic ecosystems.

Each year, Forest Service managers in the Pacific Northwest Region perform anywhere from 250 to 900 miles of stream restoration projects to help salmon, steelhead, and other aquatic species. Flitcroft's species mapping work helps to document the distribution of those species, potentially helping restoration biologists determine where to prioritize their work.

"I tell fisheries biologists new to their job in the region that they need to know the species they are responsible for in their area, and Flitcroft's work is a good tool to start that process. It also helps other forest managers and leaders understand and appreciate the immense aquatic biodiversity they are responsible to maintain on national forests across the nation," says James Capurso, the regional fisheries biologist for the Forest Service's Pacific Northwest Region.

Resource managers in other parts of the country are also seeing the value of the dashboard and the research behind it. One of whom is Amy Commens-Carson, the regional fisheries program manager for the Forest Service's Southern Region. A major part of her position is working with and communicating across the region with partners such as Trout Unlimited, The Nature Conservancy, and the National Forest Foundation.

"Becky's research has come at a really great time," Commens-Carson says. "She's developed excellent visual tools, which helps me tell the story of why we have to conserve and restore aquatic habitat."

"It's especially important in the [Forest Service] Southern Region, where we have phenomenally high aquatic biodiversity. Her product is the conversation starter. I use it in all my presentations, because maps tell a good story."

In addition to providing clear and detailed visual tools, Commens-Carson says her linking of aquatic species with forest cover is something that previously did not exist at the national scale. "National forest lands may be one of the last strongholds for protecting these aquatic species," she says.

Writer's Profile

John Kirkland has been writing about science, higher education, and business for more than 20 years. He lives in Portland, Oregon.

"There's biology in everything, even when you're feeling spiritual."

—Helen Fisher, anthropologist

Featured Tool

Flitcroft, R.; Hester, H.; Shively, D. 2024. National Aquatic Biodiversity Assessment Dashboard. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. https://research.fs.usda.gov/pnw/products/dataandtools/tools/national-aquatic-biodiversity-assessment-dashboard.

For Further Reading

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Science
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Scientist Profiles

REBECCA FLITCROFT is a research fish biologist with the Pacific Northwest Research Station. She earned her Ph.D. in fisheries science from Oregon State University. Her primary lines of research include multiscale salmonid ecology, stream network analysis, climate change and salmonid life history, and integrated watershed management. She is particularly interested in statistical and physical representations of stream networks in analysis and monitoring to more realistically represent stream complexity and connectivity for aquatic species.

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BROOKE PENALUNA is a research fisheries biologist with the Pacific Northwest Research Station. Her work focuses on understanding the effects of climate change, forest harvest, and other disturbances on fish in both riparian and aquatic habitats. She is the lead scientist at the Forest Service's H.J. Andrews Experimental Forest, a 16,000-acre site in Oregon's western Cascades dedicated to the research of forests, streams, and watersheds. Penaluna holds a Ph.D. in fisheries science from Oregon State University.

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